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# *Indian Standard*

# METHODS OF TEST FOR COMMERCIAL BLASTING EXPLOSIVES AND ACCESSORIES

## Part II EXPLOSIVES

## Section I Explosives, General

( First Reprint JULY 1983 )

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*March* 1975

# *Indian Standard*

# METHODS OF TEST FOR COMMERCIAL BLASTING EXPLOSIVES AND ACCESSORIES

## PART II EXPLOSIVES

## Section I Explosives, General

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# *Indian Standard*

# METHODS OF TEST FOR COMMERCIAL BLASTING EXPLOSIVES AND ACCESSORIES

## Part II EXPLOSIVES

### Section I Explosives, General

## 0. FOREWORD

**0.1** This Indian Standard ( Part II/Sec 1 ) was adopted by the Indian Standards Institution on 28 September 1973, after the draft finalized by the Explosives and Pyrotechnics Sectional Committee had been approved by the Chemical Division Council.

**0.2** The explosives industry in India was for a considerable time confined only to the ordnance factories. However, during the last two decades other manufacturing units have come into existence. It was, therefore, considered necessary to formulate specifications for various commercial explosives and explosive accessories produced by the industry. Before laying down specifications, it was felt necessary to prepare standard methods of test.

**0.3** Testing of commercial explosives is of utmost importance for ensuring their safety during transport and handling, stability in storage and adequate life and performance under all conditions of use. Test methods included in this standard cover these aspects for all the groups of explosives under consideration.

**0.4** Depending upon the origin and type of the explosives, a large number of test methods are in vogue, which though similar in nature, differ in minor details of experimental procedure and expression/interpretation of results.

**0.5** It is a difficult task to select a particular method as the best. Therefore, choice has been effected in favour of those methods, for which sufficient experience and experimental data is available and which are mutually acceptable to all concerned, namely, the producers, the inspecting authorities and the consumers in the field.

**0.6** The test methods cover both general and permitted explosives and accessories like detonators, detonating fuses and safety fuses. They do not cover all items but include those which are currently used and manufactured in the country. The methods of test for various explosives and explosive accessories covered under different parts of this standard are the following:

| | |
|---|---|
| Part I | Gun powder ( black powder ) |
| Part II/Sec 1 | Explosives, general |
| Part II/Sec 2 | Explosives, permitted |
| Part III | Detonators general, and permitted |
| Part IV | Detonating fuses |
| Part V | Safety fuses |

**0.7** In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

## 1. SCOPE

**1.1** This standard ( Part II/Sec 1 ) prescribes the methods of test for general explosives used for commercial blasting purposes.

**1.1.1** The tests specified are suitable for both nitroglycerine and non-nitroglycerine explosives except where specifically stated.

## 2. QUALITY OF REAGENTS

**2.1** Unless specified otherwise, pure chemicals and distilled water ( *see* IS : 1070-1960† ) shall be used in tests.

NOTE — 'Pure chemicals' shall mean chemicals that do not contain impurities whic affect the results of analysis.

## 3. TEST METHODS

### 3.1 Abel Heat Test

**3.1.0** *General* — The Abel heat test is applicable to any explosive which forms oxides of nitrogen on decomposition. When the test sample i heated, oxides of nitrogen are liberated more or less rapidly according t the stability of the material. Traces of oxides of nitrogen are detected b means of brownish line produced on starch-potassium iodide test paper The time taken to reach the standard tint gives a comparative indicatio of the stability of the explosive sample under test.

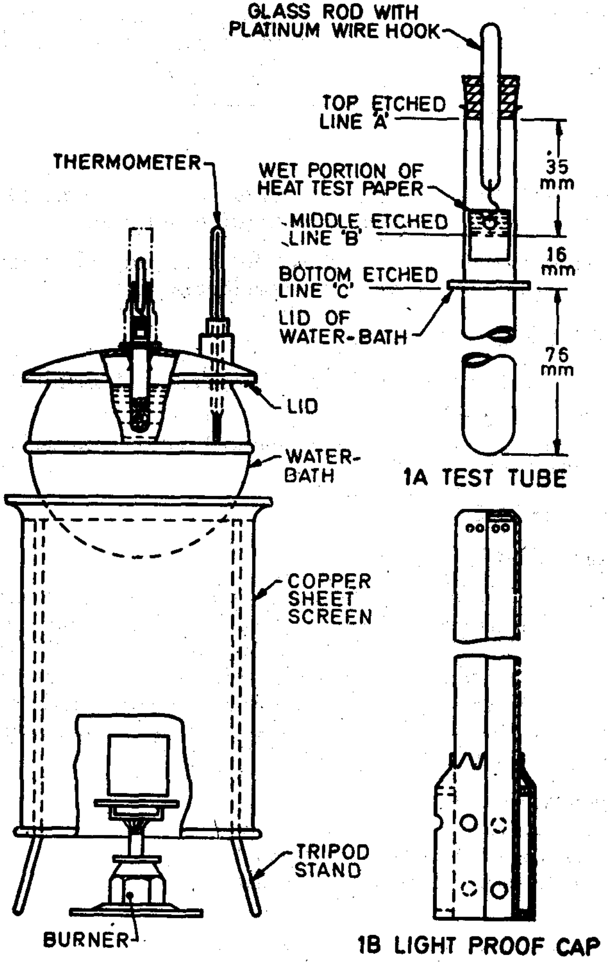
**3.1.1** *Apparatus* — as shown in Fig. 1.

---

*Rules for rounding off numerical values ( *revised* ).

†Specification for water, distilled quality ( *revised* ).

**3.1.1.1** *Water-bath* — as shown in Fig. 1, consisting of a spherical copper vessel which is provided with a loose lid of sheet copper. The latter has seven holes, six of which accommodate heat test-tubes while the seventh holds the thermometer. Brass clips or wire cages are soldered around the holes on the underside of the lid to hold the test-tubes and thermometer in position. Metal discs or adjustable covers are used during



1A TEST TUBE

1B LIGHT PROOF CAP

Fig. 1 Abel Heat Test Apparatus

testing to cover any holes which are not in use. The bath is supported on a tripod stand supported by a screen of a sheet copper and the supply of heat is regulated by adjusting the size of the burner or lamp flame.

**3.1.1.2** *Heat test-tubes* — made of borosilicate glass engraved with three marks as shown in Fig. 1A.

**3.1.1.3** *Light-proof caps* — as shown in Fig. 1B. The ventilated light-proof cap serves to shield the test paper from light during the major part of the test.

**3.1.1.4** *Rubber ring* — for placing around the test-tube to minimize the escape of steam and to provide additional support for the tube.

**3.1.1.5** *Glass rod with platinum wire hook* — The test paper ( *see* **3.1.2.2** ) is supported in the test-tube by means of a glass rod terminating in a platinum wire hook and passing through a perforated rubber stopper ( *see* Fig. 1A ).

**3.1.1.6** *Thermometer* — of suitable range and standardized every three months against a reference thermometer.

**3.1.1.7** *Glass plate with perforation* — for resting heat test papers on when piercing.

**3.1.1.8** *Nest of sieves* — made of copper alongwith lid and receiver.

**3.1.1.9** *Rubber stoppers* — cleaned by scouring in hot water and drying in oven at 50°C.

**3.1.2** *Reagents*

**3.1.2.1** *Glycerine* — *See* IS : 1796-1961*.

**3.1.2.2** *Heat test paper* ( *starch-potassium iodide paper* ) — It shall be procured from the Chief Inspectorate of Military Explosives ( CIME ), India or any other source approved by CIME.

**3.1.2.3** *Standard tint paper* — It shall be procured from the Chief Inspectorate of Military Explosives ( CIME ), India or any other source approved by CIME.

**3.1.3** *Procedure*

**3.1.3.1** *Preparation of test sample* — The test sample shall be prepared as prescribed in the relevant material specification.

---

*Specification for crude and refined glycerine.

**3.1.3.2** The water bath is fitted and is levelled and filled with water up to the outflow. It is placed on a tripod stand of convenient height in such a position that the heat test tint can readily be observed by reflected light. No part of the apparatus shall be exposed to direct sunlight.

**3.1.3.3** The thermometer fixed in the rubber stopper is inserted in the wire cage provided for the purpose on the underside of the lid of the water bath to a depth of 7·5 cm. The water is heated to the required temperature and maintained at a constant temperature and depth. The temperatures for the various explosives shall be as prescribed in the relevant specification.

**3.1.3.4** The glass rod with platinum wire hook is inserted in the rubber stopper. A test paper is then removed from the brown glass bottle by means of the forceps, placed on the glass plate so that its edges coincide with the lines on the plate, and pierced by passing a needle through the paper and the hole in the plate. The test paper is then held by means of the forceps, and a mixture of equal volumes of water and glycerine is applied to the upper edge of the test paper by means of a glass rod or dropping bottle, in sufficient quantity to moisten the upper half of the test paper by the time the test is complete. The platinum wire hook of the glass rod is then passed through the hole in the paper. At no time the operator shall touch the paper with fingers.

**3.1.3.5** The rubber stopper carrying the glass rod and test paper is at once firmly pressed into the test-tube containing the explosive to be tested until the bottom of the stopper coincides with the top line *A* etched on the test-tube, and the position of the glass rod is adjusted, so that the lower edge of the wet portion of the test paper, which edge is to be approximately horizontal, coincides with the middle etched line *B* on the test-tube as shown in Fig. 1A. The test-tube is then inserted in one of the wire cages of the lid of the water bath, so that the bottom line *C* etched on the test-tube coincides with the upper surface of the lid. The rubber ring is pressed down on the bath and the light proof cap placed in position over the tube.

**3.1.3.6** The quantities of the various explosives to be placed in the test-tube shall be as specified in the relevant specification. The test paper shall not be inspected by lifting the cap until shortly before the time explosive ought to stand the test.

**3.1.3.7** The test is completed when the faint brown line, which after a time makes its appearance at the margin between the wet and the dry portions of the test paper, equals in depth of tint the brown line on the standard tint paper. Note the time elapsing between the introduction of the tube into the bath and the production of a tint equal to the standard.

**3.1.4** *Precautions* — After the test is finished, the explosive shall be carefully removed from the tubes, and the tubes thoroughly washed out with tap water by means of the test-tube brush. They shall be rinsed out and allowed to drain for a few minutes. The washing shall be repeated with water, the tubes rinsed, allowed to drain, and finally dried in an air oven at 100°C. The tubes shall be allowed to cool to room temperature before being used again.

### 3.2 Freezing and Thawing Test

**3.2.1** *Procedure* — Take the explosive in the form of unwrapped 100 g cartridge in a test-tube of suitable dimensions. Close the tube with a velvet cork and keep at a temperature of —3°C to —6°C for 16 hours ( freezing ) followed by 8 hours at room temperature. Repeat the cycle three times ( 3 days ) and examine the explosive for any abnormality in respect of gel segregation/oozing out of nitroglycerine.

**3.2.2** *Application* — The test is applicable only to nitroglycerine explosives of gelatinous type.

### 3.3 Liquefaction Test

**3.3.1** *Procedure* — From the explosive under test, cut a cylinder, the length of the cylinder being equal to the diameter. Make the ends flat. Place the cylindrical sample so made on a flat wooden board without wrapper. Secure the sample in position by a pin passing vertically through its axis on the board. Keep the sample in this condition for 144 hours ( six days ) at a temperature of 30 to 33°C and a relative humidity of 50 ± 10 percent. Examine the cylinder for any change in its height and sharpness of the edges.

Note — The tests prescribed under **3.2** and **3.3** are useful for evaluating a new store and are not necessary for routine testing.

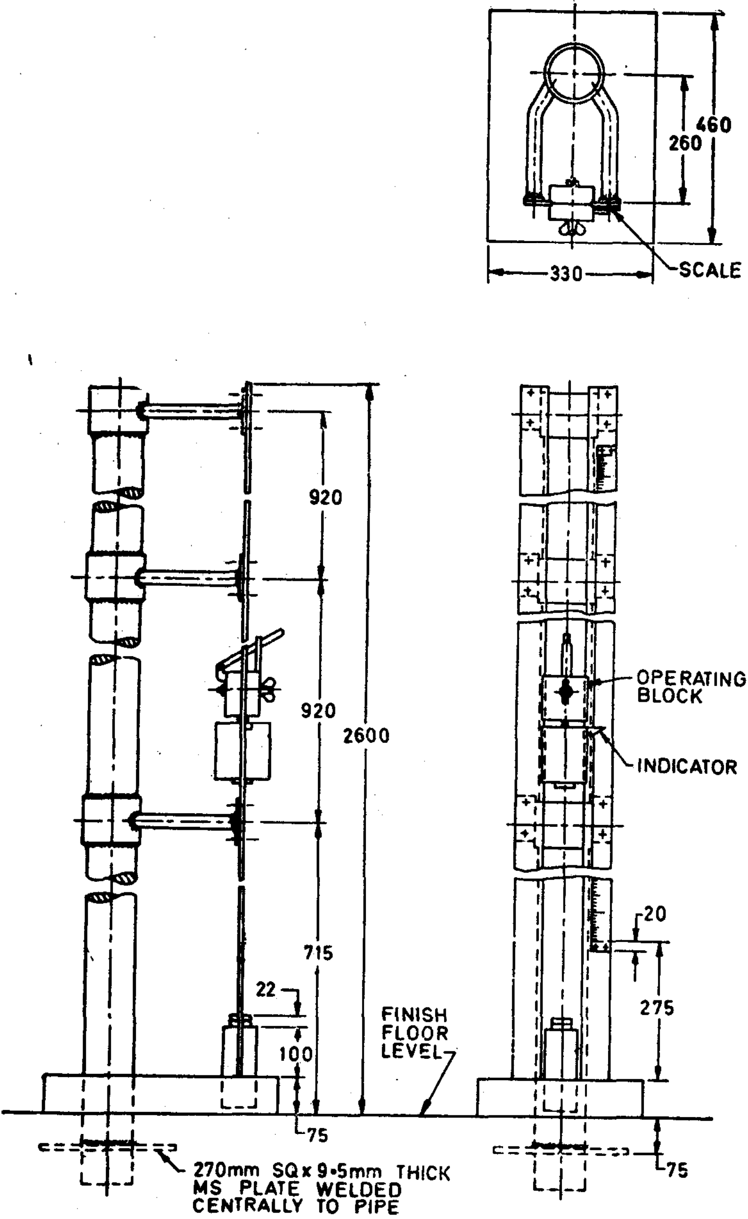
**3.3.2** *Application* — The test is applicable only to nitroglycerine explosives of gelatinous type.

### 3.4 Impact Sensitivity Test ( Fall Hammer Test )

**3.4.0** *General* — The resistance of an explosive to initiation or decomposition by impact gives an indication of its safety in handling, transportation and use. The test consists of dropping a known mass from a known height on to a known quantity of explosive kept in between the surfaces of two stainless steel Hoffmann rollers ( vicker hardness 950-980 ) of 6 mm diameter which are kept in position by the steel collar. The maximum height at which no detonation or decomposition takes place in 10 consecutive tests and the minimum height at which at least one detonation or decomposition takes place in 10 consecutive tests is determined.

**3.4.1** *Apparatus*

**3.4.1.1** *Fall hammer test apparatus* — as shown in Fig. 2.



All dimensions in millimetres.

FIG. 2 FALL HAMMER TEST APPARATUS

3.4.2 *Procedure*

3.4.2.1 *For gelatinous and powder explosives* — Weigh accurately 20 mg of the explosive in an aluminium boat. Transfer this explosive uniformly on the top surface of the lower Hoffmann roller ( *see* **3.4.0** ) kept inside the collar. Keep the upper roller on top of the explosive. Raise the 'release mechanism' of the apparatus to a definite height. Take a hammer of suitable mass ( ½ kg, 1 kg, 2 kg, 5 kg, 7·5 kg or 10 kg ) and fix it to the release mechanism. Drop the hammer ( by operating the release mechanism ) on to the top surface of the upper Hoffmann roller. Determine the maximum height at which in 10 consecutive tests no detonation or decomposition takes place and the minimum height at which at least one decomposition takes place in 10 consecutive tests.

It is expressed as, for example, critical height = 40-50 cm which means the explosive from a height of 40 cm does not decompose or detonate in 10 consecutive tests with hammer of a particular mass but from a height of 50 cm it does so at least once in 10 such tests. Repeat these operations with nitroglycerine and compare the impact sensitivity of the test sample with that of nitroglycerine.

3.4.2.2 *For liquid explosives* — Take a 6-mm dia piece of Whatman filter paper No. 42 or equivalent. Soak the filter paper piece in liquid explosive. Place the explosive soaked filter paper in between the two Hoffmann rollers. Follow the procedure given under **3.4.2.1**.

3.4.3 *Precautions* — The following precautions shall be observed:

a) Use shatter proof protective goggles while carrying out the test.

b) Do not try to push out the jammed Hoffmann rollers containing explosive in between them.

c) In case of no detonation or decomposition from a particular height, adjust either the mass or height of fall of the hammer to ensure that the explosive detonates or decomposes.

d) The surface of the Hoffmann rollers shall be smooth and flat.

e) Do not use dented rollers for the test.

3.4.4 *Application* — The method is applicable to all explosives.

### 3.5 Frictional Impact Sensitivity Test ( Torpedo Friction Test )

3.5.0 *General* — This test gives a measure of sensitiveness of explosives to friction and impact, friction playing a predominating part. The test consists in allowing a torpedo shaped striker of known mass ( 1/4 kg, 1/2 kg or 1 kg ) made of mild steel ( vicker hardness 240-250 ) to slide down an inclined plane set at a selected angle, on to a sample of substance mounted on a mild steel anvil.

**3.5.1** *Apparatus*

**3.5.1.1** *Torpedo friction testing apparatus* — as shown in Fig. 3.

**3.5.2** *Procedure*

**3.5.2.1** Set the angle of inclination of the 'V' groove at 70° to the horizontal. Insert the anvil in position and fix it rigidly in the base plate by tapping it on the edge by a wooden/brass hammer. Allow the torpedo of a suitable mass ( *see* **3.5.0** ) to slide from a low height on to the anvil.

**3.5.2.2** Place 20 mg of explosive on the anvil at the point where the torpedo makes contact with the anvil as determined in **3.5.2.1**. In case the effect of any foreign matter on the sensitivity is required to be determined, add appropriate quantity of foreign matter with the test sample. Keep the torpedo on the 'V' groove at a known height. Allow the torpedo to slide down the groove and impinge on the explosive. Find out the maximum height at which no detonation or decomposition takes place in 10 consecutive tests.

**3.5.3** *Precautions* — The following precautions shall be observed:

a) Use shatterproof protective goggles while carrying out the test.

b) Do not use dented anvil for the test.

c) Smoothen out the impacting surface of the torpedo after every test.

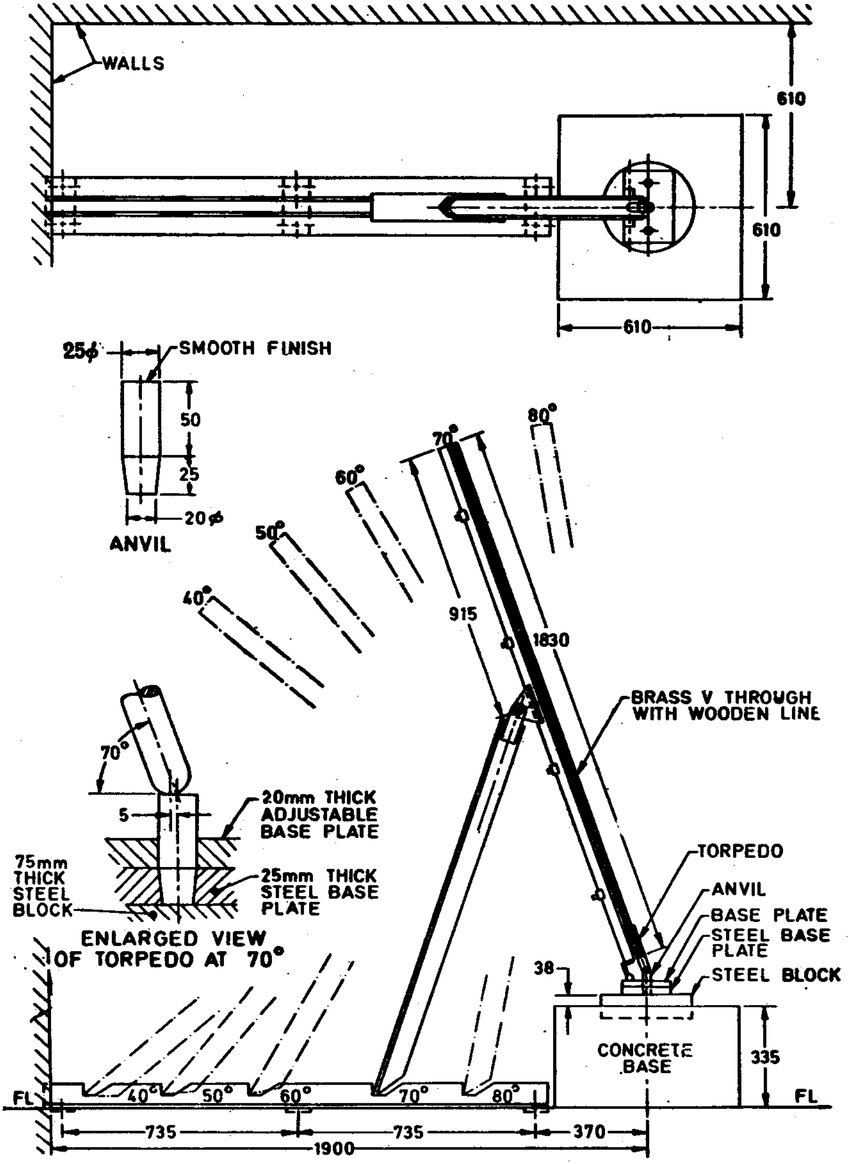
**3.5.4** *Application* — The method is applicable to all explosives.

## 3.6 Air Gap Sensitivity Test ( Ardeer Double Cartridge Test )

**3.6.0** *General* — The object of this test is to determine the sensitivity of a charge of explosive ( receptor ) to initiation by another charge ( donor ) located at a known distance apart but in line with the first charge. The larger the distance over which transmission of propagation of detonation takes place, the more sensitive is the explosive.

**3.6.1** *Procedure*

**3.6.1.1** *Preparation of charge* — Take at least 200 mm long cartridge and cut it into two equal lengths to form donor and receptor. In case of cartridges having length less than 200 mm take more cartridges so that the minimum length can be obtained and cut one end of the composite cartridges and make out donor and receptor samples. If the explosive runs freely, cover the cut ends by small pieces of paper and retain the papers in position by rubber bands.



All dimensions in millimetres.

Fig. 3 Torpedo Testing Apparatus

Prick a hole at the uncut end of one of the test samples using a brass/aluminium pricker for inserting the detonator prior to firing of the shot. With the cut ends facing each other, place the cartridges in line and at a known distance apart, roll the cartridges in three-fold manila paper of the type used in wrapping explosives. Retain the cartridges in position by radially driven pins.

**3.6.1.2** *Firing of the charge ( unconfined )* — In case of firing of the charge electrically, retain the exploder or the firing panel key in possession and insert a No. 6 strength detonator into the pricked hole of the cartridge with the bare leads of the detonator short circuited.

In case of firing with safety fuse, nip off about 5 cm of the coil ends and take about 1 metre of freshly cut fuse.

Take a No. 6 strength plain detonator, insert one end of the fuse piece so that the fuse end is in light contact with the explosive charge inside the detonator and crimp the detonator on to the fuse using a crimper. Insert the detonator into the pricked end of the cartridge. Lay the explosive charge on a steel shaft ( 75 cm dia ) or 45 kg rail.

**3.6.1.3** In case of firing of the charge electrically, connect the two bare leading wires of the detonator to the firing cable. While making connection, keep the exploder or firing panel safety key in possession. Fire the charge from a safe distance.

In case of firing of the charge using safety fuse, light the fuse end and withdraw to a safe distance. Determine the maximum gap over which the receptor cartridge detonates.

Record the results giving the type of explosive, diameter of the cartridge and the maximum gap in cm over which the receptor cartridge detonates in duplicate tests.

**3.6.1.4** *Firing of the charge ( confined )* — Take a 3 to 5 mm thick steel pipe having an internal diameter about 5 to 6 mm greater than the diameter of the explosive charge and a length about 15 to 20 cm greater than the length of the explosive charge and follow the procedure outlined in **3.6.1.2**.

Fill the annular space between the explosive charge and the inner wall of the pipe with loose sand. Stem the ends with wet earth, and follow the procedures outlined in **3.6.1.3**.

**3.6.2** *Precautions* — The following precautions shall be observed:

a) Retain the exploder or firing panel key in possession while connecting the bare leads of the detonator with the firing cable. Also keep the bare leads of the detonators short-circuited prior to making connection with the firing cable.

b) Collect the fragments of undetonated explosives after firing of the charge.

c) In case of misfires, wait for at least 10 minutes before approaching the charge if it is fired electrically. In case of misfires while firing with safety fuse, wait at least for half an hour before approaching the charge.

3.6.3 *Application* — The method as such is applicable to both general explosives and permitted explosives. In case the test is carried out with any initiator or booster other than No. 6 strength detonator record the type, quantity, size and material of the initiator or booster used along with the air gap sensitivity results.

### 3.7 Velocity of Detonation Using Microtimer

3.7.0 *General* — The time ' *t* ' taken by the detonation front to traverse a known distance ' *d* ' in the explosive is measured by the timer in microseconds. Thus the velocity of detonation ( VOD ) is denoted as $d/t$ and is expressed as kilometre per second.

3.7.1 *Apparatus*

3.7.1.1 *Microtimer* — The microtimer is an electronic instrument which is suited for measuring very short time intervals, such as those involved in detonation processes. Two signals which define the beginning and end of the time interval to be measured are used as ' start ' and ' stop ' signals to operate a gate. This gate turns on and off a constant current supply to a capacitor and the voltage developed across the capacitor is measured by an electrometer voltmeter circuit. Thus if the capacitor starts with zero potential difference across it, the potential registered by the voltmeter circuit at the end of the time interval is directly proportional to the time interval. By suitably selecting the various circuit constants the voltmeter is made to read directly in microseconds.

3.7.2 *Procedure*

3.7.2.1 *Preparation of VOD probes* — Take four pieces of enamelled copper wire of 0·32 to 0·56 mm diameter, each of 60 cm length. Pick up two enamelled wires at a time and twist together one end over 3 to 4 cm. Remove the insulations of the free ends of the wires. The twisted wires with the bare ends are known as ' VOD probes '.

3.7.2.2 *Preparation of the charge* — Take at least a 200 mm long cartridge. In case of smaller cartridges, take two cartridges, cut one end of each, keep the cartridges in contact with bare ends facing each other and roll in a 3-fold manila paper to make a single cartridge. Take a brass or aluminium pricker and make a hole at one end of the cartridge for inserting detonator.

Make two radially driven holes of 2 mm diameter through the cartridge at a known distance apart in such a way that the first hole is at least 1·5 times the diameter away from the end of the detonator in the cartridge. Insert the twisted ends of the probes one each into the diametrically driven holes. Split open the twisted ends and fix them in position by cellotape.

**3.7.2.3** *Operation of the microtimer* — The cartridge as prepared above is detonated suitably and the interval of the propagation of the detonation wave between the two probes is measured on a microtimer described in **3.7.1.1.**

In case of firing with safety fuse, take a one metre length of safety fuse and nip off about 5 cm of the fuse ends, insert one end of the fuse into the detonator and crimp the detonator on to the fuse and insert the detonator into the end-hole of the cartridge.

Report the results giving the type of explosive, diameter of the charge and the velocity of detonation in km/s.

**3.7.3** *Precautions* — The following precautions shall be observed:

a) Keep the timer key and exploder key ( in case of firing by exploder ) always in possession while connecting the detonator to the shot firing cable.

b) In case of incomplete detonation, carefully collect all the fragments of the charge.

c) In case of misfire wait at least for 5 min in case of shot firing electrically or for at least 30 min in case of shot firing with safety fuse before approaching the shot.

d) The timer shall be calibrated once in 6 months.

**3.7.4** *Application* — This test as such is applicable to both general and permitted explosives. In case the test is carried out using any initiator or booster other than No. 6 strength detonator, record the type, quantity, size and material of the initiator or booster along with the VOD results.

### 3.8 Velocity of Detonation by Dautriche Method

**3.8.0** *General* — The time lag between the initiation of two ends of a length of detonating fuse of known velocity of detonation, inserted radially into an explosive charge at a known distance ( $d$ ) apart, causes the two detonation fronts travelling in opposite direction along the length of the detonating fuse to meet at a point ( $\Delta L$ ) away from the centre of the fuse. Knowing the distance ( $d$ ), the velocity of the detonation ( $V_0$ ) of the detonating fuse, the velocity of detonation ( $V$ ) of the explosive is calculated and is expressed in km/s.

**3.8.1** *Apparatus* — The arrangement is shown in Fig. 4.

**3.8.2** *Procedure*

**3.8.2.1** *Preparation of the lead plate* — Take a lead plate of 30 cm length, 5 cm width and 1·5 cm thickness with a longitudinal groove of 6 mm depth at the centre. Take the plate and make a scratch along the width near one end of the plate.

Take a one metre length of detonating fuse of known VOD, mark its middle point and seal the ends using cellotape. Lay the detonating fuse in the groove of the lead plate in such a way that the centre of the detonating fuse is in line with the scratch on the lead plate.

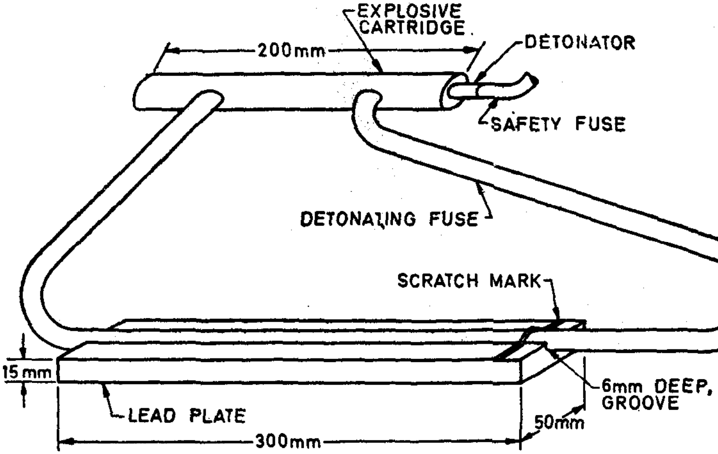


FIG. 4 ARRANGEMENT FOR THE DETERMINATION OF VELOCITY OF DETONATION BY DAUTRICHE METHOD

**3.8.2.2** *Preparation of the charge* — Take at least a 200 mm long cartridge. In case the length of the cartridge is small, take two cartridges, cut one of the ends of both, keep the cartridges with the cut ends in contact and roll the cartridges in 3-fold manila paper so as to make a single cartridge.

Make a hole at one end of the cartridge using a brass or aluminium pricker for inserting the detonator. Make two radially driven holes of equal depth into the cartridge at a known distance apart in such a way ~~that the~~ first hole is at least 1·5 times the diameter of the cartridge away from the detonator end of the cartridge.

**3.8.2.3** *Arrangements for firing* — Lay the cartridge on a steel bar or rail. Lay the lead plate on the side of the cartridge. Insert the ends of the detonating fuse into the radially driven holes in such a way that the longer arm of the detonating fuse protruding out of the lead plate is inserted into the hole nearer to the detonator end of the cartridge.

Lay the cable. Follow the shot firing procedures. Insert a No. 6 detonator into the end hole of the cartridge and connect the leads of the detonator to the cable. In case of firing by safety fuse, use a freshly cut 1 metre length of fuse, crimp a No. 6 detonator to the fuse and then insert the detonator into the end hole of the cartridge. Fire the shot.

Collect the lead plate and measure $\Delta L$ that is the distance of the meeting of the two detonation fronts from the centre of the detonating fuse ( the point where the two detonation fronts meet on the lead plate is distinguished by a sharp mark at the back of the plate ).

**3.8.3** *Calculation*

$$\text{Velocity of detonation } ( V ), \text{ km/s} = \frac{d \times V_0}{2 \Delta L}$$

where

$d$ = distance between two ends of the detonating fuse,

$V_0$ = velocity of detonation of the detonating fuse in km/s, and

$\Delta L$ = distance between middle point of standard detonating fuse ( scratch on the lead plate ) to the point on the lead plate where the two detonation fronts travelling in opposite directions meet.

**3.8.3.1** Record the results giving the type of explosive, diameter of the charge and the velocity of detonation in km/s.

**3.8.4** *Precautions* — The following precautions shall be observed:

a) In case of misfire, wait at least for 10 min in case of electric shot firing or for 30 min in case of firing by safety fuse.

b) In case of incomplete detonation collect all fragments of the explosive.

c) In case there is no mark on the lead plate, repeat the VOD measurement using a fresh length of detonating fuse and lead plate.

**3.8.5** *Application* — The test is applicable to both general and permitted explosives. In case the test is carried out with any initiator or booster other than a No. 6 strength detonator, record the type, quantity, size and the material of the initiator or booster along with the VOD results,

### 3.9 Velocity of Detonation Under Steel Tube Confinement

**3.9.0** *General* — The object of this measurement is to have an indication of the velocity of detonation under steel tube confinement.

**3.9.1** *Procedure*

**3.9.1.1** *Preparation of steel tube* — Take a steel tube of 2 to 3 mm wall thickness and of sufficient length and having a diameter 5 to 6 mm greater than the diameter of the charge to be fired. Make two through holes of 6 mm diameter on the steel tube at a known distance apart in such a way that the first hole is at least 1·5 times the diameter of the cartridge away from the end of the detonator in the cartridge.

**3.9.1.2** *Preparation of the charge* — Take at least a 200 mm cartridge and prick a hole at one end of the cartridge. In case of smaller cartridges, take two such pieces, cut one end of each and, with the cut ends facing each other, roll in a 3-fold manila paper so as to make a single cartridge.

Insert radially driven pins into the cartridges so as to retain the cartridges in position and make a hole at one end of one of the cartridges for inserting the detonator prior to firing the shot.

Wrap the cartridge with layers of manila paper in such a way that the wrapped cartridge just fits in the steel pipe. Gently push the cartridge into the steel pipe in such a way that the cartridge takes position against the holes on the tubes. Insert VOD probes or detonating fuse ends depending on the method of VOD measurement and follow the procedures laid down under **3.7** or **3.8**.

Record the results of measurement giving the type of explosive, diameter and the VOD in km/s.

**3.9.2** *Application* — The test is applicable to both general and permitted explosives. In case the test is carried out using any initiator or booster other than a No. 6 strength detonator, record the type, quantity, size and the material of the initiator or booster along with the VOD results.

**3.9.3** *Precautions* — Follow the same precautions as under **3.7.3** and **3.8.4** depending upon the method used.

### 3.10 Waterproofness Test

**3.10.0** *General* — The object of this test is to find out the relative waterproofness of various explosives under laboratory conditions of testing.

**3.10.1** *Procedure*

**3.10.1.1** *Preparation of sample* — Take 5 cartridges of 25 × 200 mm or 32 × 150 mm size. Make three 6-mm dia holes ( having a depth slightly less than the radius of the cartridge ) on the cartridge surface in the form of a spiral, each hole 25 mm apart in such a way that the first hole is at least 50 mm from one end of the cartridge and also the first and the third holes are in line with each other. Make a detonator hole at one end of the cartridge of such depth that there is at least a clearance of 25 mm between the end of this hole and the first hole on the cartridge surface. Plug the end hole with a dummy detonator.

**3.10.1.2** *Storage of samples under water* — Take a polyethylene/metal trough of 20 cm height and fill it with water. Keep the cartridges horizontally under 15 cm depth of water.

**3.10.1.3** *Examination and firing of the sample* — Examine the cartridges after every half an hour. Remove the cartridges when they start becoming soggy. Remove the dummy detonator from the end hole, replace it with a No. 6 detonator and fire the charge following the recommended shot firing procedure.

**3.10.1.4** Report the results giving the maximum period for which the cartridge remained under water without giving rise to partial/incomplete detonation.

**3.10.2** *Application* — The method is applicable to all types of explosives.

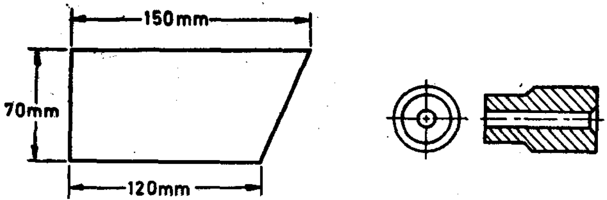
## 3.11 Strength ( Power ) of Explosives ( Ballistic Mortar Method )

**3.11.0** *General* — The strength or power of a high explosive is determined by measuring the angle of recoil produced by a 10 g charge of the explosive fired in a Dupont ballistic mortar and is expressed as a percentage of polar blasting gelatine.

**3.11.1** *Apparatus* — as shown in Fig. 5.

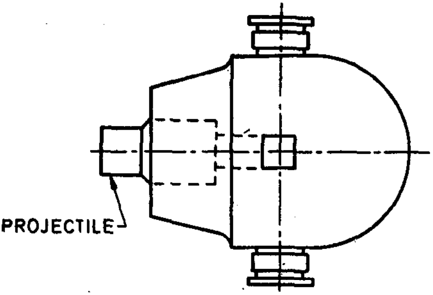
**3.11.1.1** The apparatus consists of a pendulum composed of a mortar which serves as its bob, suspended by a rigid frame of light aluminium plates on a knife-edge. It is so designed that the firing of a small ( normally 10 g ) charge of an explosive propels a tightly fitting projectile and the recoil of the mortar is recorded by the movement of the spring loaded clip on the scale kept in contact with a pointer fixed on the mortar. The scale is graduated in degrees and minutes.

**3.11.1.2** The total mass of the assembly is approximately 470 kg. The mortar, weighing 310 kg is provided with two connecting chambers. The outer chamber, bored in from the muzzle of the mortar, has a diameter of 22 mm and is 125 mm deep. The inner chamber, arranged centrally behind the first, is 50 mm in diameter and 140 mm deep. The outer chamber is designed to receive a 16·5 kg steel projectile and the inner chamber is designed to receive the explosive charge. The initial clearance between projectile and its chamber is approximately 0·076 mm. A maximum



TINFOIL WRAPPER

PROJECTILE



MORTAR AND PROJECTILE

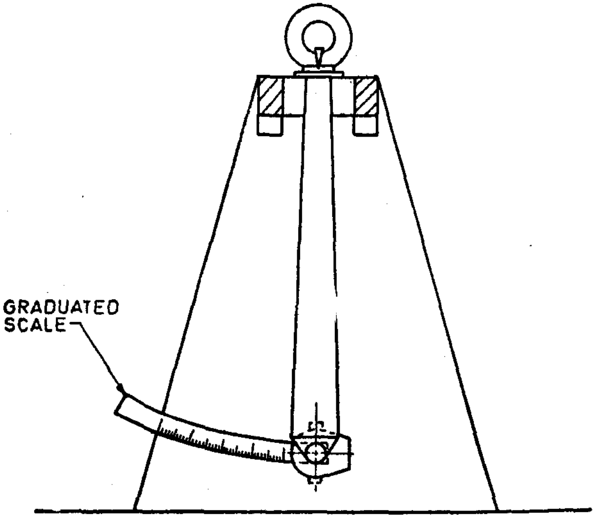


FIG. 5 DUPONT BALLISTIC MORTAR

clearance of 0·15 mm is allowed. The distance from the centre of the explosion chamber to the axis of suspension is 3 metres. The assembly is so proportioned that the centre of percussion coincides approximately with the axis of the firing chamber.

**3.11.2** *Procedure*

**3.11.2.1** *Preparation of the sample* — Open out the cartridge taking care that the explosive is not contaminated with wax from the shell. Reject 10 mm of the explosive at both ends of the cartridge. Mix the remainder of the sample thoroughly.

**3.11.2.2** *Preparation of test sample* — Weigh 10 g of the explosive correct to the nearest centigram in an aluminium boat. Take a tin foil of 150 × 120 × 70 mm width ( trapezoidal shape as shown in the figure ) and make a shell of 22 mm diameter and 50 mm length having one end closed. Prepare two such shells for each sample of explosive under test.

Transfer the weighed quantity of the explosive into the shell. Keep the tinfoil shells containing explosive in an air-tight container.

**3.11.2.3** *Preparation of the charge* — Take a No. 6 copper ordinary detonator. Take a 40 cm length of safety fuse from a coil whose ends are nipped off by 5 cm. Insert one end of this fuse into the detonator carefully so that the fuse end is in contact with the detonator composition. Crimp the detonator on to the fuse.

Make a hole in test sample in the tinfoil shell. Insert the detonator into the tin foil shell containing explosive and close the open end of this shell. Use extra quantity of tinfoil to close the open end of the shell properly.

**3.11.2.4** *Loading of the charge* — Clean the inside of the hole of the mortar and the outside surface of the projectile using a piece of clean cloth. Scrape off the sticky residue in the hole or the projectile using a steel blade or knife. Take the charge, pass the safety fuse through the axial hole in the projectile.

Take enough tinfoil to wrap the tinfoil cartridge upper end in such a way that it seals the gap between the fuse and the countersunk mouth of the axial hole in the projectile, and the tinfoil cartridge is flush with the surface of the projectile.

Insert the projectile carefully into the cavity in the hole and push it home so that the cartridge takes position in the firing chamber. Allow the mortar to come to rest. Move the sliding cursor to 5° mark on the quadrant.

**3.11.2.5** *Firing of the shot* — Light the end of the fuse protruding out of the projectile using a match stick and withdraw from the mortar room. Wait till the shot fires, enter into the room and note down the deflection produced by the explosive. Fire duplicate shots for each explosive and also for polar blasting gelatine.

In case a variation of more than 5 min is observed in the swing in duplicate shot, carry out a further set of duplicate tests.

**3.11.2.6** *Calculation*

$$\text{Strength of explosive} = \frac{1 - \text{Cos } A}{1 - \text{Cos } A_0} \times 100$$

where

$A$ = swing produced by the explosive under test, and

$A_0$ = swing produced by the polar blasting gelatine.

**3.11.2.7** Record the results giving the particulars of the explosive and its power as a percentage of that of polar blasting gelatine or TNT fired under the same conditions.

NOTE — The mass of each tinfoil shell shall be 0·7 to 0·8 g and the tin content shall not be less than 98 percent.

**3.11.3** *Precautions* — The following precautions shall be observed:

a) In case of misfire, wait for at least half an hour and carry out procedures for handling misfires.

b) Crimp detonator carefully.

c) Use freshly out fuse and use only copper tube ordinary detonator.

d) Before loading the projectile ensure that the trapping pit sawdust and hessian bags kept to arrest the projectile are moist.

e) After firing each shot, clean the inside of the hole of the mortar and the projectile surface thoroughly.

f) In case of gun powder and permitted explosives, fire a 10 g polar blasting gelatine shot after every duplicate shot.

g) The shot shall be replaced when the clearance between the shot and the cavity in the mortar is more than 0·15 mm.

**3.11.4** *Application* — The method as such is applicable to those explosives which are sensitive to initiation by No. 6 strength detonator only. For explosives which are not sensitive to initiation by No. 6 strength detonator, the power measurement shall be done using a higher strength detonator. In that case the strength of the detonator used shall also be specified alongwith the power results. For the explosives which are not sensitive to initiation by detonators, the method given under **3.13** shall be adopted.

### 3.12 Strength ( Power ) of Explosives ( Trauzl Lead Block Method )

**3.12.0** *General* — The lead block test is carried out by firing a weighed quantity of an explosive in an axial cavity made in a cylindrical lead block. The increase in the volume of the cavity is measured and the result of the test is expressed as millilitre enlargement per gram of the explosive.

**3.12.1** *Apparatus and Material*

**3.12.1.1** *Lead block* — Melt a sufficient quantity of lead of 99·9 percent purity to cast a cylindrical block of 200 × 200 mm. Keep the surface of the metal molten by a flame while casting. Ensure that the temperature does not exceed 450°C and that no cracks are developed between layers of lead used in making the block. Remove the finished block from the mould and check the dimensions. The depth of the central cavity shall be 125 mm and it shall have diameter of 25 mm. Ensure that the base of the block is flat and free from any cavity.

**3.12.1.2** *Tinfoil wrapper* — The wrapper used shall have a mass of not more than 0·7 to 0·8 g and shall have a size of 150 × 120 × 70 mm width. The tin content shall not be less than 98 percent. Make the tinfoil shells of 22 mm diameter and 50 mm length by rolling on a wooden rod.

**3.12.1.3** *Stemming* — Fine dry sand passing through 425-micron IS Sieve shall be used for stemming.

**3.12.2** *Procedure* — Weigh 10 g of the material to be tested, place it in the tinfoil shell of 22 mm diameter × 50 mm length as given in **3.12.1.2**. Take a 30 cm length of freshly cut safety fuse and crimp a No. 6 strength ordinary detonator on to one end of the safety fuse. Insert the detonator into the charge and close the upper end of the shell. Place the prepared cartridge in the cavity of the lead block and push it to the bottom of the cavity by means of 10 mm diameter wooden rod. Fill the remaining space with sand and brush away any excess. Light the fuse and after detonation of the explosive, clean out the cavity by inverting the lead block and determine the enlargement in the volume of the cavity by filling it with water from a graduated burette. Subtract the original volume of the cavity from this and divide by the mass of the charge and report the result giving the particulars of the explosive and enlargement of the volume as millilitre per gram of explosive. No allowance is made for the effect of the detonator.

**3.12.3** *Precautions* — The following precautions shall be observed:

a) In case of misfire, wait at least for 30 min before approaching the block and then the procedures for handling misfires shall be strictly followed.

b) While carrying out the test, the temperature of the block shall be maintained at 27 ± 2°C.

c) The same block shall not be used for more than one test.

d) While casting ensure that no cracks are developed on the block.

**3.12.4** *Application* — The test is applicable to detonator sensitive explosives only.

NOTE — The test can be carried out using electric detonator also. The procedures and precautions of firing electrically are identical to those given under **3.6.2** and **3.7.3**.

### 3.13 Strength ( Power ) of Detonator Insensitive Explosives ( Ballistic Mortar Method )

**3.13.0** *General* — In case of detonator insensitive explosives, the method outlined as in **3.11** cannot be followed. For such explosives, the method of power measurement consists of mixing different proportion of sensitizers such as PETN, polar blasting gelatine, etc, with the explosive and firing 10 g charges of the mixed explosive in the ballistic mortar. The angle of recoil of the mortar obtained with different proportions of sensitizer in the explosive or the corresponding power values are plotted on a graph paper and the plot ( angle of recoil or power values *versus* percentage of sensitizer ) is extrapolated to zero sensitizer. From this, the power of the explosive without sensitizer can be determined.

**3.13.1** *Apparatus* — same as prescribed under **3.11.1**.

**3.13.2** *Procedure*

**3.13.2.1** *Preparation of the sample* — Take all the ingredients of the explosive as fine as possible and make a 100 g batch of the explosive.

**3.13.2.2** *Preparation of the test sample* — Make out 10 g charges of the explosive with different percentages ( 20 percent, 40 percent, 60 percent, 80 percent, 100 percent ) of sensitizer mixed in the explosive in tinfoil wrapper as outlined in **3.11.2.2**. For each percentage of sensitizer make duplicate charges.

**3.13.2.3** *Preparation of the charge* — Follow the same procedure as prescribed in **3.11.2.5**.

**3.13.2.4** *Loading of the charge* — Follow the same procedure as prescribed in **3.11.2.4**.

**3.13.2.5** *Firing of the shot* — Follow the same procedure as prescribed in **3.11.2.5**.

**3.13.3** *Calculation* — Calculate the power of the mixed explosive at each percentage of sensitizer using the formula as given in **3.11.2.6**, plot the angle of recoil or the corresponding power values on a graph paper, extrapolate the plot to zero sensitizer and determine the power of the explosive without sensitizer.

**3.13.4** *Precautions* — The precautions as given under **3.11.3** shall be observed.

# INTERNATIONAL SYSTEM OF UNITS ( SI UNITS )

**Base Units**

| *Quantity* | *Unit* | *Symbol* |
|---|---|---|
| Length | metre | m |
| Mass | kilogram | kg |
| Time | second | s |
| Electric current | ampere | A |
| Thermodynamic temperature | kelvin | K |
| Luminous intensity | candela | cd |
| Amount of substance | mole | mol |

**Supplementary Units**

| *Quantity* | *Unit* | *Symbol* |
|---|---|---|
| Plane angle | radian | rad |
| Solid angle | steradian | sr |

**Derived Units**

| *Quantity* | *Unit* | *Symbol* | *Definition* |
|---|---|---|---|
| Force | newton | N | 1 N=1 kg.m/$s^2$ |
| Energy | joule | J | 1 J=1 N.m |
| Power | watt | W | 1 W=1 J/s |
| Flux | weber | Wb | 1 Wb=1 V.s |
| Flux density | tesla | T | 1 T=1 Wb/$m^2$ |
| Frequency | hertz | Hz | 1 Hz=1 c/s ($s^{-1}$) |
| Electric conductance | siemens | S | 1 S=1 A/V |
| Electromotive force | volt | V | 1 V=1 W/A |
| Pressure, stress | Pascal | Pa | 1 Pa=1 N/$m^2$ |

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